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Verification and Validation of the Night Vision Goggle Tactical Decision Aid

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13. ABSTRACT *(Maximum 200 words)*

The Night Vision Goggle (NVG) Tactical Decision Aid (TDA) was developed to support Army operations in situations requiring accurate predictions of light levels. Minimum thresholds of illumination are used by the Army to plan and execute missions during periods of darkness or near darkness. The NVG TDA is part of a suite of decision aids that will become part of the fielded Integrated Meteorological System (IMETS). The IMETS is a system designed to be operated by Air Force Staff Weather Officers supporting Army tactical operations in peacetime and in times of conflict. The verification and validation (V & V) effort discussed in this report is part of the Battlefield Environment Directorate configuration management plan to field physically correct and user-friendly software to Army units over the entire conflict spectrum. The V & V described is thorough and shows that the NVG TDA is physically correct and applicable for accreditation before use.

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Contents

1. Introduction

The Night Vision Goggle (NVG) tactical decision aid (TDA) is a computer software application used to determine the suitability of NVG use based on existing or forecast meteorological conditions in a specific area of interest. It provides solar and lunar illumination values and positions based on computer calculated ephemeris data. The TDA considers the general effects of clouds and precipitation on illumination levels, based on typical surface weather observations of prevailing meteorological conditions.

The NVG TDA is part of a suite of decision aids delivered to the Program Executive Office, Command and Control Systems (PEOCCS), Project Director (PD), Integrated Meteorological System (IMETS) as part of a fielded IMETS software applications package. Before this formal release, the NVG TDA was used under the guidance of Battlefield Environment Directorate (BED) scientists to support U.S. Army field training and command post exercises at various locations in the United States and Europe. This TDA was included in the Initial Operational Test and Evaluation of the Block I IMETS conducted at Fort Hood, TX during the fall of 1993.

Although the NVG TDA went through acceptance testing before the release to PEOCCS PD IMETS, formal independent verification and validation (V & V) efforts were never accomplished. The V & V described here is a result of BED's efforts to include V & V as part of future software releases to U.S. Army weather support personnel. This process is part of the BED configuration management program to ensure that accurate, user-friendly applications are fielded.

The NVG V & V discussed here, ideally, would have started at the beginning of the software development cycle and continued throughout the life-cycle of the NVG TDA until its final fielding accreditation. This effort was initiated at BED after the release of the software, and certain V & V procedures had to be omitted because of the late start. The accurate identification of software problems is an integral part of providing the end-user with a physically and theoretically sound product.

The following definitions from Army Regulation 5-11, *Army Model and Simulation Management Program* [1] are provided for completeness (M & S in these definitions refers to model and simulation):

a. Verification

(1) Verification is the process of determining that M & S accurately represent the developer's conceptual description and specifications. Verification evaluates the extent to which the M & S has been developed using sound and established engineering techniques. The verification process involves identifying and examining the stated and pertinent unstated assumptions in the M & S, examining interfaces with input databases, ensuring that source code accurately performs all intended and required calculations, reviewing output records, performing structured walk-through techniques to determine if M & S logic correctly performs intended functions, and performing M & S sensitivity analyses. Unexpected sensitivity (or lack of sensitivity) to key inputs may highlight a need to review the M & S algorithm for omissions or errors.

(2) Verification also includes appropriate data certification and M & S documentation (e.g., programmer's manual, user's guide, and analyst's manuals).

(3) Verification should normally be performed by an independent V & V (IV & V) agent but remains the responsibility of the M & S proponent to ensure accomplishment.

b. Validation

Validation is the process of determining the extent to which M & S accurately represent the real-world from the perspective of the intended use of the M & S. The validation process ranges from single modules to the entire system. Ultimately,

the purpose is to validate the entire system of M & S data, and operator-analysts who will execute the M & S. Validation methods will incorporate documentation of procedures and results of any validation effort.

The types of validation appropriate for the NVG TDA are (1) face validation, which determines whether an M & S, based on performance, seems reasonable to people who are knowledgeable about the system being modeled; and (2) peer review, which involves critical and detailed analyses of the internal representativeness of the M & S and outputs by personnel who are experts in the functional areas represented in the M & S. This determination is based on the selected examples of validation given in the document. The following sections will focus on the NVG TDA V & V starting with a review of technical documents used in the development of the NVG TDA and other documentation primarily used to corroborate methods or values presented in the TDA. The investigator's comments are included where deemed necessary.

2. Technical Documentation Review

A comprehensive review of the technical documents used to develop the NVG TDA and a review of technical materials related to the software release of the NVG TDA to PD IMETS were made. The review was necessary for the validation of the theoretical concepts incorporated into the computer model. The summary is presented in this section on a document-by-document basis with cross-references where necessary for comparison of values and techniques used. The validation described is conceptual, as described by Dale K. Pace in his article "Modeling and Simulation," [2] because of the maturity level of the computer application model and the relative timeliness of this V & V effort. The V & V started late in the research and development cycle because of the delayed adoption of accepted configuration management practices by BED. In theory, the V & V should have started with the initial software development and continued through the IMETS release and beyond as new improvements to the computer model are made. The first document reviewed is the basis for the illumination calculations in the NVG application prepared by the National Defence Research Organization TNO in the Netherlands. [3] AFGL-TR-82-0039, *Solar Radiative Flux Calculations from Standard Surface Meteorological Observations*, [4] is also discussed in some detail, because it is the basis for the cloud cover information applied here. Supporting documents are reviewed next. The NVG TDA user's guide is reviewed for accuracy and applicability for operational use as seen by the evaluator.

The technical basis for the NVG TDA computer application was taken from *The Computer Program ILLUM: Calculation of the Positions of Sun and Moon and the Natural Illumination*, PHL 1982-13 by Ir. A.C. van Bochove from the Physics Laboratory at the National Defence Research Organization TNO. [3] The computer program described in this report was used for solar and lunar ephemeris calculations and for the associated illumination values. This reference also provides a reasonable constant value for natural illumination in which there is little or no contribution to light levels from the sun or moon. The report contains a full description of the FORTRAN computer code used.

The NVG program calculates illumination levels from user-supplied geographical latitude and longitude of an earth-based observer and on the local mean solar time. The calculations are reported to be within 1 min of arc for a specified valid interval. Illumination levels are calculated for the sun and moon based on a horizontal plane (flat earth) for clear skies. The computer code consists of two parts: (1) astronomical, which calculates solar and lunar azimuth and altitude and lunar phase; and (2) illumination, which calculates illumination levels and the distance of the sun and moon from the earth. Not surprisingly, the program results are not reliable during eclipses; however, the computer code is structured to warn of these occurrences. The altitude dependence of the illumination and the effect of the lunar phase are taken from accepted empirical data published in the literature.

As mentioned earlier, a constant value for natural illumination is used. For conditions in which the sun and moon are well below the observer's horizon, a value of 1.1×10^{-3} lx (lumens (lm) m^{-2}) is used, which is consistent with values found in the RCA *Electro-Optics Handbook* [5] of 1.0×10^{-3} lx. Values for maximum lunar illumination (full moon) were 0.267 lx from both references.

Another primary document for the NVG TDA was AFGL-TR-82-0039, *Solar Radiance Flux Calculations from Standard Meteorological Observations*, [4] by Ralph Shapiro of Systems and Applied Sciences Corporation under contract to the Air Force Geophysics Laboratory (now Phillips Laboratory). The results of Shapiro's work and resulting computer models were used to include the effects of cloud cover on the amount of illumination reaching the ground. In its most complex form, this model calculates the solar radiation incident at or near the earth's surface through n-layers of a model atmosphere through a system of $2n + 2$ linear equations. These equations are a closed set of equations that account for the physical processes of reflection, transmission, and absorption of the electromagnetic radiation along its path.

To be consistent with the standard methodology for reporting cloud cover, the n-layers were taken to be three discrete cloud layers representing low, middle, and high clouds. The effects of the surface of the earth (albedo) were also considered in a cursory fashion. Specific coefficients, primarily dependent on

the cloud amount and thickness, were developed. After reflection, transmission, and absorption coefficients are determined, based on direct measurements of radiation reaching the ground and simultaneous cloud type and amount observations, the model offers the capability of determining the mean transmission and reflection characteristics of any individual cloud type. The model described here was tested against independent data and found to be accurate. The calculations used in this work were derived from scattering theory and Monte Carlo simulations.

Nine cloud types were chosen to represent the cloud types commonly observed. The Synoptic Cloud Code recognizes other cloud types, but their occurrence is rare and they are seldom observed. The lowest cloud types considered are cumulus, stratocumulus, and stratus in which stratocumulus and stratus are combined. Middle clouds are made up of altostratus and altocumulus. Thin and thick cirrus clouds represent the high cloudiness and are combined but differentiated by their thickness (thin and thick). The case in which precipitation is occurring is the least reliable solar flux calculation used in the model because of the infrequent occurrences leading to a small number of case studies and the several different cloud types present during precipitation events. During precipitation, ground-based observers, typically, report the clouds accurately only up to the first overcast layer unless the observer has detailed supplemental information from meteorological satellites or from another source such as balloon soundings or aircraft reports. Because of this, thick clouds are assumed at all three levels (low, middle, and high) when precipitation is occurring.

In this application, simple radiative transfer processes are considered. Processes such as aerosol and molecular scattering and absorption and ozone and water vapor absorption are treated in the most rudimentary fashion. "Since the largest effect of insolation is due to clouds and since we are approximating the atmosphere with only three layers, a more sophisticated treatment of the clear layers was deemed unwarranted." [4]

The respective transmission, reflection, and absorption for each of the three cloud layers in Shapiro's treatment were handled accurately and correctly according to atmospheric physical processes. Even though this treatment is

greatly simplified by considering a simple three-layer atmosphere, the dynamics of the radiation reaching the earth's surface is very complicated. Shapiro rigorously and completely handles this physical process. [4]

The evaluator did extensive analyses of the cosine dependence on solar radiation with altitude. The analyses showed that the variation in the insolation was largely independent of the angle of incidence at altitudes below 10,000 ft with the variation in the fourth decimal place at angles less than 90°. Because most Army operations involving NVGs occur at low altitudes, the incidence angle of the radiation with altitude was considered insignificant, especially, in view of the other simplifying assumptions already made.

Finally, the *Technology Exploitation Weather TestBed (TEWTB) User's Guide and Technical Reference for the Block I Integrated Meteorological System (IMETS)*, PSL-92/60 [6] was reviewed for content and consistency. This document was prepared for and intended to be used by individuals unfamiliar with the IMETS but who possessed some basic computer operations skills. Some inconsistencies were noted in this review; however, it is a very useful document.

The user's guide employs the terminology night vision devices interchangeably with NVG. This is misleading because the Army has other equipment intended for use under low-light level conditions, which are not NVGs. Examples of these are the starlight scope used for night operations with the M-16 rifle and the tank gunner's sight used in night armor operations. The NVG application is geared more toward aviation uses for nighttime flying at low altitudes, not other operations.

References are made to conditions as being GO or NO-GO in some cases and as being Favorable/Marginal/Unfavorable in others. The terms GO/NO-GO should be avoided in any kind of a decision aid because of their restrictive nature and seeming inflexibility to adapt to changing situations. These are decision aids for use by operational decision makers, and they should not appear to be directive in nature.

Computer jargon is used in several places. This is probably acceptable for the intended audience for this early release. A careful review of future user's guides intended for operational use by Air Force Staff Weather Officers will be necessary to avoid potential confusion. For example, alphanumeric display could be replaced with something like tabular display for clarity.

The user's guide is not internally consistent in places. In some places, three cloud layers are mentioned, and in other places, four are mentioned. The model actually has four layers with the surface of the earth being a distinct surface along with the three cloud layers previously mentioned. There should be a specific input for atmospheric obscurations such as fog, smoke, haze, etc. that apply to partial (-X) and total (X) obscurations. The obscuration entries should be part of the forecaster input. The input form (screen) should have examples of expected input. For example, the month could be represented be 1-12 or Jan-Dec.

The reference should contain definitions of the unfamiliar terminology used. Some people operating the IMETS will not remember the difference between nautical and civil twilight. Inclusion of these definitions will make the document a valuable reference for the operator. The guide is complete and fairly accurate for its stage of development and intended use in the research and development cycle.

3. Software Testing

During testing, the NVG TDA computer software was exercised approximately 11.5 h in seven separate sessions. The testing was done on the ACCS4 system located in building 1646 room 18. The most current version of the Block I IMETS baseline software resides on the ACCS4 system. The purpose of the testing was to evaluate the user friendliness of the NVG software suite from an operator's point of view and to determine obvious inconsistencies in the computer application. Other errors were not discovered in the testing because of the evaluator's inability to determine and analyze every possible scenario. The following is a list of the notes taken during the software testing phase of this validation effort:

3.1 Notes Taken 1 Nov 93

Hardware Platform: ACCS4
Time on System: Approximately 2 h

Went through the example scenario in the user's guide

NVG input screen has a typo, "Time difference between loca and GMT (hrs);" loca should be local. A discrepancy report form was filed.

The user must make sure that an item is highlighted before it is accepted by the program. Simply changing the entry is not enough; this is not a big deal but could give a person without computer operation experience a fit. Training on the use of the x-windows system should clear this up.

It is not obvious that latitude and longitude are in the form deg, min, sec from looking at the values. Maybe the units should be included here. This is particularly true when there is only one digit for minutes and seconds.

(6) in the user's guide example "PLOT OF GO/NO-GO TIMES" is not a menu option in the NVG application, but "PLOT OF FAVORABLE/UNFAVORABLE" is.

Daily event times should have four digits. Morning times should have the leading zero, if needed. For example, 730 should be 0730. This would conform to the military (24-h clock) way of telling and representing time.

Suggestion: Moonrise and moonset are not explicitly defined. It might be a good idea to just have a table with the nautical and civil twilights as well as moonrise/moonset. Sunrise and sunset could also be included because they are often used by Army operations personnel.

3.2 Notes Taken 4 Nov 93

Hardware Platform: ACCS4
Time on System: Approximately 2 1/2 h

This is the disclaimer statement that precedes the application:

> UNVERIFIED, DEVELOPMENTAL SOFTWARE FOR TRAINING AND EVALUATION ONLY Operational use requires near real-time meteorological data from surface, upper air, and satellite sensors and weather forecasts for the local area. Optimally, the host computer will automatically ingest the meteorological data and process weather decision aids. Before operational use this software must be approved according to DoD Directive 5000.3 and procedures given in DoD-STDS 2167A and 2168.

See discrepancy report forms for errors detected.

The form that is displayed for the daily event times should be made so that the dates can be read after the slide bar is used to reveal the data that would not fit on the screen. The headers (BMNT, EENT, etc.) should also be visible when the data slides down for the user to view it. It is real hard to tell what data is in the columns and rows unless they are identified in some way.

Data that were requested for 31 Nov 93 (no such date) were identical to the data for 1 Dec 93. This is a good finding in that when a bogus date is chosen, all other data are not shifted one day.

3.3 Notes Taken 9 Nov 93

Hardware Platform: ACCS4
Time on System: 2 1/2 h

The ACCS4 computer had to be rebooted in order for the system to work. It is not obvious that the system was down when the application was entered.

PLOT OF FAVORABLE/UNFAVORABLE Worked well for 1 day. The screen depicts a red-amber-green display which is easy to read and understand.

PLOT OF ILLUMINATION LEVELS This is a line graph. The yellow band is hard to distinguish as yellow, if it is small. There should be some indication of what is favorable and unfavorable on the chart.

ILLUMINATION CALCULATION This seemed to work fine but the time reference either Z or L should be on the input value box/screen. It will default to 0000Z if nothing is input.

The plot of favorable/unfavorable comes up behind other screens when it should come up in front automatically.

When changed, the NVG input screen should come up with the new values that were input rather than what they were when the program was entered. The site ID, weather, cloudiness, and GMT time difference come up to the original values when the NVG program is exited.

The Light Level Planning Calendar (LLPC) is hard to follow and probably should be color coded or something. The legend goes away when the slide bar is used.

Whenever a ground or surface type is specified, the value of its corresponding albedo should be available to the operator. Maybe it would be helpful if the operator could change the albedo based on local conditions and/or knowledge of the surface.

3.4 Notes Taken 12 Nov 93

Hardware Platform: ACCS4
Time on System: 1/2 h

The ACCS4 system booted normally. Twilight values from the NVG program were compared to hard copy printout values from the Nautical Almanac Office at the U.S. Naval Observatory in Washington, DC.

Table 1 lists the comparisons of the data from the NVG Application and the table from the White Sands Missile Range weather forecasting facility (C-Station) (the values are the deviation of the NVG program to the Nautical Almanac values. All non-zero values are positive unless noted otherwise).

These data show some differences but they are minor and could be attributed to differences in calculation methodology or some sort of a computer routine that rounds values off differently. These values are certainly within reasonable limits based on the accuracy needed for Army operations. There is good internal consistency between these two independent sources of data. The same analysis was conducted for the other eleven months of the year and the largest absolute difference between the two methodologies was 5 min. The stated requirement for accuracy was that the computer-generated data be within 5 min on either side of the actual event. The Nautical Almanac Office data are widely used throughout the world by U.S. Government agencies. Based on this, the NVG application data are good and very useful.

The values for latitude and longitude that were input to the NVG application were the same as those provided for C-Station tables to the Naval Observatory. These values were:

a. Latitude = 32° 23' North
b. Longitude = 106° 29' West

Table 1. List of the comparisons of the data from the NVG application and the table from C station

January 1993				
Date	BMNT[a]	BMCT[b]	EECT[c]	EENT[d]
1	2	2	-3	-2
2	2	3	-3	-3
3	2	3	-3	-3
4	1	3	-3	-3
5	2	3	-3	-3
6	2	2	-4	-3
7	2	2	-3	-4
8	2	2	-3	-4
9	2	1	-3	-3
10	2	1	-4	-3
11	2	2	-4	-4
12	2	1	-3	-4
13	2	1	-3	-4
14	2	1	-3	-3
15	2	1	-4	-4
16	2	1	-4	-4
17	1	1	-4	-4
18	1	0	-4	-4
19	2	1	-3	-3
20	2	1	-3	-4
21	1	0	-3	-4
22	1	1	-4	-4
23	2	1	-4	-4
24	1	0	-4	-4
25	1	1	-4	-3
26	1	0	-4	-4
27	1	1	-4	-4
28	2	0	-3	-4
29	1	1	-3	-4
30	1	0	-3	-4
31	1	1	-4	-5

[a]BMNT = beginning morning nautical twilight (center of the solar disk 12° below the horizon in the morning)
[b]BMCT = beginning morning civil twilight (center of the solar disk 6° below the horizon in the morning)
[c]EECT = ending evening civil twilight (center of the solar disk 6° below the horizon in the evening)
[d]EENT = ending evening nautical twilight (center of the solar disk 12° below the horizon in the evening)

NOTE: The definitions for BMNT, BMCT, EECT, and EENT were taken from the *Glossary of Meteorology*. [7]

3.5 Notes Taken 15 Nov 93

Hardware Platform: ACCS4
Time on System: 1 h

The ACCS4 would not enable me to get to the White Sands Missile Range map display and the NVG application would not execute. I tried three or four different times. There was no outward indication that anything was wrong with the application except that it would not come on as expected.

3.6 Notes Taken 16 Nov 93

Hardware Platform: ACCS4
Time on System: 1 h

On 16 Nov, the system behaved itself and worked normally. I made copies of the solar ephemeris from the ACCS for comparison with the C-Station data. The results are discussed in the 12 Nov notes.

3.7 Notes Taken 18 Nov 93

Hardware Platform: ACCS4
Time on System: 2 h

The following was noted:

a. On the LLPC, the user cannot maximize the application window screen but the capability to do it is still active. The system has a protection mechanism built in that requires you to log back in. Since this maximize capability really doesn't do anything, it probably should be disabled to avoid confusion.

b. The same process described above also happens with the map in that the user must log back in. The map does come up on the whole screen after log-in. This is confusing to the operator.

c. When the LLPC is displayed, it is really only partially represented on the screen and the slide bars must be used to see other parts of the table. When the user tries to print the screen, all that is printed is the information on the computer screen. In order to get a printout of the table, the operator must make multiple copies of screens. The window will not expand to show the complete table.

d. The table on the LLPC is hard to understand. Possibly it could be colored for favorable, marginal, and unfavorable or contoured with only a few large letters/symbols in each area. This would make the table interpretation easier for the operator or anyone who was receiving a briefing from a hard-copy print or directly from the computer screen.

Errors that were noted in this testing were fully documented on established discrepancy report forms and reported to the responsible parties in accordance with established BED configuration management procedures.

4. Conclusions and Recommendations

The NVG TDA is complete and accurate based on its stage of development in the IMETS scheme. It is based on sound physical principles and is usable and trustworthy for limited operational considerations. Before the software and hardware can be fielded, they must be made user-friendly. Any errors noted in this memorandum report and subsequent V & V efforts must be corrected. The NVG TDA must continue to be fully tested and independently evaluated in each baseline phase of its development before it is fielded as part of an operational IMETS for Army weather support. As in the past, periodic testing of changes and upgrades to the computer code by the software developers are necessary to verify the correctness of the computer code and its interaction with its associated computer hardware platform. Independent V & V must be thoroughly conducted before future IMETS releases.

References

1. Headquarters Department of the Army, *Army Model and Simulation Management Program*, Army Regulation 5-11, Issued by Washington, DC, 10 June 1992.

2. Pace, D. K., "Modeling and Simulation," *Phalanx, The Bulletin of Military Operations Research*, **26**, 3, ISSN 0195-1920, The Johns Hopkins University Applied Physics Laboratory, p 27-29, 1993.

3. van Bochove, Ir. A.C., *The Computer Program ILLUM: Calculation of the Positions of Sun and Moon and the Natural Illumination*, PHL 1982-13, Physics Laboratory TNO, National Defence Research Organization TNO, The Netherlands, 1982.

4. Shapiro, R., *Solar Radiative Flux Calculations from Standard Surface Meteorological Observations*, AFGL-TR-82-0039, Scientific Report No. 1, Systems and Applied Sciences Corporation, Document published under contract F19628-81-C-0042 for the Air Force Geophysics Laboratory, Hanscom AFB, MA, 1982.

5. *Electro-Optics Handbook*, Technical Series EOH-11, RCA, Solid State Division, Electro-Optics Devices, Lancaster, PA, Reprinted, 1978.

6. Physical Science Laboratory, *Technology Exploitation Weather TestBed (TEWTB) User's Guide and Technical Reference for the Block I Integrated Meteorological System (IMETS)*, PSL-92/60, Document published under contract DAAD07-91-C-0139 (WAO 92-3.24-2), Las Cruces, NM, November 1992.

7. Huschke, R. E., Ed., *Glossary of Meteorology*, American Meteorological Society, 1959.

Acronyms and Abbreviations

BED	Battlefield Environment Directorate
C-Station	White Sands Missile Range weather forecasting facility
IMETS	Integrated Meteorological System
LLPC	Light Level Planning Calendar
NVG	Night Vision Goggle
PD	Project Director
PEOCCS	Program Executive Office, Command and Control Systems
TDA	tactical decision aid
V & V	verification and validation

Bibliography

Harris, J. E., "A Technology Exploitation Weather TestBed for Army Applications," In *Proceedings of the Eighth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology*, presented by J. R. Elrick, Atlanta, GA, p 5-9, January 5-10, 1992.

Nautical Almanac Office, *Lunar Ephemeris Tables for White Sands Missile Range, NM for 1993*, U.S. Naval Observatory, Washington, DC.

Physical Science Laboratory, PSL-93/57, under contract DAAD07-91-C-0139 (WAO 93-3.24-2), *Verification, Validation, and Assessment for the Technology Exploitation Weather TestBed (TEWTB)*, Las Cruces, NM, August 1993.

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